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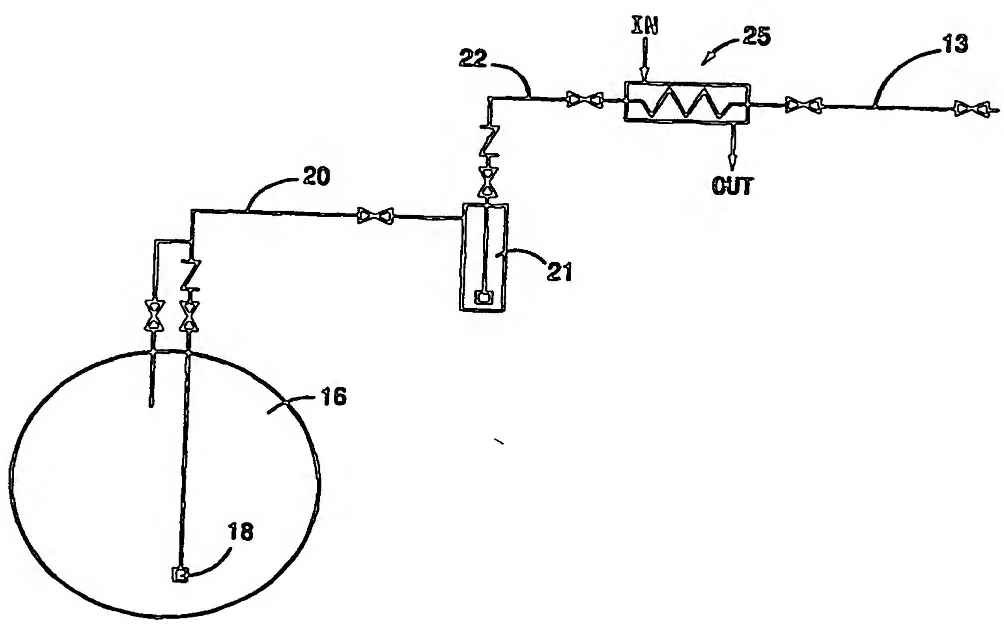

(57) Abstract

A system and a method for regasifying LNG aboard a carrier vessel before the re-vaporized natural gas is transferred to shore. The pressure of the LNG is boosted (21) substantially while the LNG is in its liquid phase and before it is flowed through a vaporizer(s) (25) which, in turn, is positioned aboard the vessel. Seawater taken from the body of water surrounding the vessel is flowed through the vaporizer (25) to heat and vaporize the LNG back into natural gas before the natural gas is off-loaded to onshore facilities.

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REGASIFICATION OF LNG ABOARD A TRANSPORT VESSEL

The present application claims the priority of Provisional Patent Application serial No. 60/078438, filed March 18, 1998.

The present invention relates to the regasification of liquefied natural gas (LNG) aboard a sea-going, transport vessel before the LNG is transferred to shore as a gas and in one aspect relates to a system and method for regasifying LNG aboard the transport vessel before the revaporized LNG is transferred to shore wherein circulating seawater is used as the heat exchange medium for vaporizing the LNG aboard the vessel.

Large volumes of natural gas (i.e., primarily methane) are produced in many remote areas of the world. This gas has significant value if it can be economically transported to market. Where the production area is in reasonable proximity to a market and the terrain between the two locations permits, the gas is typically transported through submerged and/or land-based pipelines. However, where the gas is produced in locations where laying a pipeline is infeasible or economically prohibitive, other techniques must be used in getting this gas to market.

Probably the most commonly used technique for getting remotely-produced gas to market involves liquefying the gas at or near the production site and then transporting the liquefied natural gas or "LNG" to market in specially-designed, storage tanks aboard a sea-going carrier or transport vessel. The natural gas is compressed and cooled to cryogenic temperatures (e.g., -160^{0}C), thereby significantly increasing the amount of gas which can be carried in a particular storage tank. Once the vessel reaches its destination, the LNG is typically off-loaded, as a liquid, into onshore, storage tanks from which the LNG can then be revaporized as needed and transported as a gas to end users through pipelines or the like.

Where LNG markets are well established and the demand for natural gas is steady and on-going, the building and maintaining of permanent onshore storage and regasification facilities to service these markets is easily economically justified. Unfortunately, however, there are other potential markets for LNG which are short

term, seasonal, or periodic in nature (i.e., "spot markets") which do not justify the building and maintaining of the required, permanent onshore facilities, due to the long lead times involved and the high costs related thereto. This results both in (a) depriving the potential customers in these markets of relative cheap energy and (b) lost sales to the natural gas producer.

Recently, it has been proposed to transport natural gas to market and then revaporize the LNG aboard the carrier vessel before the gas is off-loading into onshore pipelines; see "AN ECONOMIC SYSTEM FOR THE LIQUEFACTION, TRANSPORTATION, AND REGAS OF NATURAL GAS USING SURPLUS LNG CARRIERS", The Society of Naval Architects and Marine Engineers, No. 1, by Gary W. Van Tassel and John W. Boylston, presented at International Maritime Symposium, Waldorf Astoria Hotel, N.Y., September 27-28, 1984; hereinafter referred to as the "Paper". In the method disclosed in the Paper, natural gas is compressed, cooled, and converted to LNG at a production site before it is loaded into the storage tanks of an available, commercial LNG carrier vessel which, in turn, is to be retrofitted with onboard vaporizers for onboard revaporizing the LNG once the vessel reaches its off-loading destination.

When the vessel reaches its destination, the LNG is withdrawn from the onboard storage tanks and its pressure is boosted by passing the LNG through booster pumps while the LNG is still in its liquid state. The LNG is then flowed through onboard vaporizers to revaporize the LNG into its gaseous state (i.e., natural gas) before the gas is flowed to shore and into pipelines for delivery to market. By using the tanks on the carrier vessel for storing the LNG at the off-loading site and then revaporizing the LNG before the gas is brought onshore, the need for expensive, onshore storage tanks and permanent regasification facilities at the off-loading site is eliminated. Also, since the pressure of the LNG is boosted onboard the vessel while it is still a liquid, the amount of compressor horsepower, otherwise needed in flowing the revaporized natural gas through the onshore pipelines, is greatly reduced if not eliminated altogether.

While regasifying LNG aboard its carrier vessel provides several recognized advantages as discussed above, the prior art systems

proposed for regasifying the LNG aboard the vessel leaves much to be desired when safety and/or ecological concerns are considered. For example, the system described in the above-cited Paper proposes to use steam from the ship's boilers as the heat-exchange medium in the onboard vaporizers for revaporizing the LNG. The live steam will needed to be piped to and through the vaporizers and will be under relatively high pressure and at high temperatures presenting additional safety hazards to the ship and crew. Additionally, any condensate contamination will result in a multi-day ship delay with extremely negative consequences on the project operation and economics.

Another recent proposal has been to use a steam-heated, water-glycol mixture as the heat-exchange medium for the onboard evaporators. Again, the steam would be taken from the ship's boilers that would require them to remain fired during the off-loading operation. Also, the piping of the live steam to various heat exchangers on the vessel will again expose the crewmen to potential safety risks if a steam line should break or spring a leak. Further, due to the toxicity of glycol, its use poses a risk both to the safety of those handling the glycol aboard the ship and also to the surrounding environment in the event the lines carrying the glycol should rupture or leak during off-loading. Accordingly, a need exists for a system for revaporizing the LNG aboard the vessel which presents the minimum risks to both the crew and to the environment.

The present invention provides a system and a method for regasifying LNG aboard a carrier vessel before the re-vaporized natural gas is transferred to shore. Basically, this is done by flowing the LNG from the LNG storage tanks aboard the carrier vessel a vaporizer(s) which is positioned aboard the vessel. Seawater taken from the body of water surrounding the vessel is flowed through the vaporizer to heat the LNG within the vaporizer and to vaporize the LNG back into natural gas before the natural gas is transported from the vaporizer on the vessel to onshore facilities.

The LNG is boosted to a high pressure (e.g., 80-100 bars) while the LNG is in its liquid phase and before passing the LNG through the vaporizer. This allows the vaporized gas, which exits the vaporizer at substantially the same pressure, to flow to shore and on through

onshore pipeline to designated facilities without requiring any further substantial compression. The seawater used in the vaporizers is taken from the body which surrounds the vessel through an inlet and is discharged from the vaporizer back into the body of water at a point through an outlet which is spaced from the inlet (e.g., at least 18 meters) so that the cooled discharged water is not recirculated through the vaporizer.

The system for carrying out the present invention basically comprised of a vaporizer train(s) aboard the carrier vessel which is adapted to receive and vaporize the LNG from the storage tanks aboard the vessel once the vessel is moored at its off-loading destination. Each vaporizer train is comprised of a booster pump which receives LNG from the storage tanks and raises the pressure of the LNG before it is passed through a vaporizer which, in turn, is positioned aboard the vessel. The vaporizer is comprised of a housing having an inlet and an outlet for flowing seawater through the vaporizer to heat the LNG and vaporize it back to natural gas before its exits the vaporizer. The inlet of the vaporizer is adapted to receive seawater directly from the body of water surrounding the vessel while the outlet is adapted to discharge the seawater back into the body of water after the seawater has passed through the vaporizer. The inlet and the outlet of the vaporizer are spaced from each other at a distance (e.g., at least 18 meters) to prevent the recirculation of the cold, discharged seawater.

By boosting the pressure of the LNG while it is still a liquid and then regasifying the LNG aboard the carrier vessel before it is off-loaded from the vessel into onshore facilities, the need for onshore storage tanks and large amounts of compressor horsepower is eliminated thereby opening new markets for the LNG. Further, by using seawater as the primary heat exchange medium for the onboard vaporizers, the present invention provides a safe and environmental-friendly method and system which presents minimal risks to both the crewmen and operators during off-loading.

The actual construction operation, and apparent advantages of the present invention will be better understood by referring to the drawings, not necessarily to scale, in which like numerals identify like parts and in which:

FIG. 1 is an illustration of a typical LNG carrier vessel retrofitted in accordance with the present invention as it is moored at an off-loading terminal;

FIG. 2 is a simplified schematical flow diagram of the onboard, regasification system of the present invention;

FIG. 3 is a side view, partly broken away of the vessel of FIG. 1;

FIG. 4 is a plan view of FIG. 3;

FIG. 5 is an expanded schematical flow diagram of the system of FIG. 2; and

FIG. 6 is an enlarged view of the vaporizer illustrated for use in the present system.

Referring more particularly to the drawings, FIG. 1 illustrates a sea-going, liquefied natural gas (LNG) carrier vessel 10 moored at its off-loading destination. As shown, vessel 10 is secured to an off-shore, bottom supported mooring structure or platform 11 by hawser 12 and is maintained in a "weather-vaned" position by a tugboat 15 or the like during the off-loading operation. An off-loading, transfer line 13 from vessel 10 is fluidly connected through a swivel or the like on moor 11 to submerged pipeline 14 which, in turn, transports the cargo from vessel 10 to an onshore pipeline 17a which, in turn, passes the gas on to the end use facilities 17.

As will be understood by those skilled in the art, it is common practice to compress and cool natural gas at or near a production area to form liquefied natural gas (LNG) which is then transported to market in specially-designed storage tanks 16 aboard vessel 10. Typically, when vessel 10 reaches its destination, it is moored to a pier 11 and the LNG is off-loaded in its liquid state onto shore where it is stored and/or revaporized before sending it on to end users as a gas. This requires the building and maintaining of onshore storage and compressor facilities which, due to the time and expense involved, may cause many small or spot markets to go unserviced.

In accordance with the present invention, the LNG from tanks 16 is revaporized aboard vessel 10 before it is off-loaded from the vessel into onshore pipeline 17a as a gas. This eliminates the need for onshore storage tanks and significantly reduces, if not

eliminates, the compressor horsepower required for getting the gas to the end users.

The system for carrying out this onboard revaporization of the LNG in accordance with the present invention is schematically illustrated in FIG. 2. Typically, the LNG is stored in tank(s) 16 as a liquid under atmospheric pressure and at a temperature of around 162° C. Once vessel 10 is securely moored at moor 11 and transfer line 13 is properly connected, LNG is pumped by submerged pump 18 from tank 16 through line 20 and is delivered to a booster pump 21 at a pressure of 6 bars. Booster pump 21, in turn, significantly raises the pressure of the LNG (e.g., to 80-100 bars) before it is passed on to vaporizer 25 through line 22. Vaporizer 25, which uses ecologically-friendly seawater as the heat exchange medium, vaporizes the LNG back into natural gas before it is flowed to shore through transfer line 13 and submerged pipeline 14 (FIG. 1).

Various types of vaporizers, which are capable of using seawater as the principal heat exchange medium, can be used in the present invention; for example "TRI-EX" Intermediate Fluid-Type LNG Vaporizer, available from Kobe Steel, Ltd., Tokyo, Japan. This type of vaporizer is illustrated in FIG. 6 and is comprised of a housing 29 having a pre-heat section 30 and a final heating section 31. Pre-heat section 30 has a plurality of pipes 32 running therethrough which fluidly connect the manifolds 34 and 35 which lie at either end of section 30 while final heating section 31 has a plurality of pipes 36 therethrough which fluidly connect manifolds 35, 37 which lie at either end of section 31.

Seawater, which is collected directly from the sea-surrounding vessel 10, is pumped into manifold 37 through intake or inlet line 40. The seawater flows through pipes 36 in final heating section 31 and into manifold 35 before flowing through pipes 32 in pre-heat section 30 and into manifold 34, from which the seawater is then discharged back into the sea through outlet line 41.

In operation, the LNG from booster pump 21 flows through inlet line 22 and into a looped conduit 33 which is positioned within the pre-heat section 30 of vaporizer 25 which, in turn, contains a "permanent" bath 38 of an evaporative coolant (e.g., propane) in the lower portion thereof. The seawater, flowing through pipes 32, will

"heat" the propane in bath 38 causing the propane to evaporate and rise within precooling section 30. As the propane gas contacts looped conduit 33, it gives up heat to the extremely cold LNG flowing therethrough and recondenses to drop back into bath 38 thereby providing a continuous, circulating "heating" cycle of the propane within pre-heat section 30.

After the LNG is "heated" in coiled conduit 33 with pre-heat section 30 flows through line 41 into final heating section 31. Baffles 42 in section 31 force the LNG to flow through a tortuous path and in contact with pipes 36 wherein heat from the seawater in pipes 36 is exchanged with the LNG to complete the vaporization of the LNG before its exits the evaporator 25 through transfer line 13 at a temperature 10°C cooler than the temperature of the seawater and at a pressure in the range of 80-100 bars, depending on the particular conditions involved.

Referring to FIGS. 3-5, a more detailed layout of an actual system in accordance with the present invention is illustrated as it may be retrofitted or originally installed on a typical LNG vessel 10. The system disclosed in these figures is comprised of a plurality (e.g., two) of individual vaporizer trains 25a, 25b. Each separator train 25a, 25b, respectively, has basically the same construction and operates in the same manner as that described above. The trains are positioned on opposite sides of vessel 10 (see FIG. 4) and operate in parallel with the outputs from both of the vaporizer trains 25a, 25b being fluidly connected into transfer line 13 for transferring the vaporized natural gas to shore.

Referring now more particularly to FIG. 3, the inlet 40 of vaporizer 25 is fluidly connected to "sea chest" 50 which is positioned below the waterline to collect seawater therein. The outlet 41 is spaced at a sufficient distance "d" (e.g., at least 18 meters) from the inlet 40 so that the "cooled" water which is being discharged through outlet 41 will not be drawn back into the sea chest 50. This prevents the significantly colder water from outlet 41 (i.e., water which has been heat-exchanged within vaporizer 25) from being recycled through the vaporizer which, if done, could substantially reduce the heating efficiency of the vaporizer.

It can be seen that by using seawater as the heat exchange medium for regasifying LNG aboard a carrier vessel before transferring the re-vaporized natural gas to shore facilities, the present invention provides a safe and ecologically-friendly system which poses almost no threat to the environment.

CLAIMS:

1. A method for regasifying liquefied natural gas (LNG) aboard a LNG carrier vessel before the LNG is off-loaded as a gas, the method comprising:

flowing the LNG from storage tanks aboard the carrier vessel for storing LNG during transport through a vaporizer which is positioned aboard the vessel;

flowing seawater taken from the body of water surrounding the vessel through the vaporizer to heat the LNG within the vaporizer and to vaporize the LNG back into natural gas; and

transferring the natural gas from the vaporizer on the vessel to onshore facilities.

2. The method of claim 1 including:

boosting the pressure of the LNG while in its liquid phase before passing the LNG through the vaporizer.

3. The method of claim 2 wherein the pressure of the LNG is boosted to a pressure in the range of 80-100 bars before the LNG is passed through the vaporizer.

4. The method of claim 3 wherein the seawater is discharged from the vaporizer back into the body of water at a point which is at least 18 meters from where the seawater is taken from the body of water.

5. A system for regasifying liquefied natural gas (LNG) aboard a LNG carrier vessel before the LNG is off-loaded as a gas, the system comprising:

storage tanks aboard the carrier vessel for storing LNG during transport;

a vaporizer positioned aboard the vessel and adapted to receive LNG from the storage tanks;

means for flowing seawater through the vaporizer to heat the LNG within the vaporizer and to vaporize the LNG back into natural gas; and

a transfer line fluidly connected to the vaporizer to transport the natural gas from the vaporizer on the vessel to onshore facilities.

6. The onboard, regasification system of claim 5 including:

means for boosting the pressure of the LNG while in its liquid phase before passing the LNG through the vaporizer.

7. The onboard, regasification system of claim 7 wherein the vaporizer comprises:

a housing having an inlet and an outlet, the inlet adapted to receive seawater directly from the body of water surrounding the vessel and the outlet adapted to discharge the seawater after the seawater has passed through the vaporizer back into the body of water wherein the distance between the inlet and the outlet is at least 18 meters.

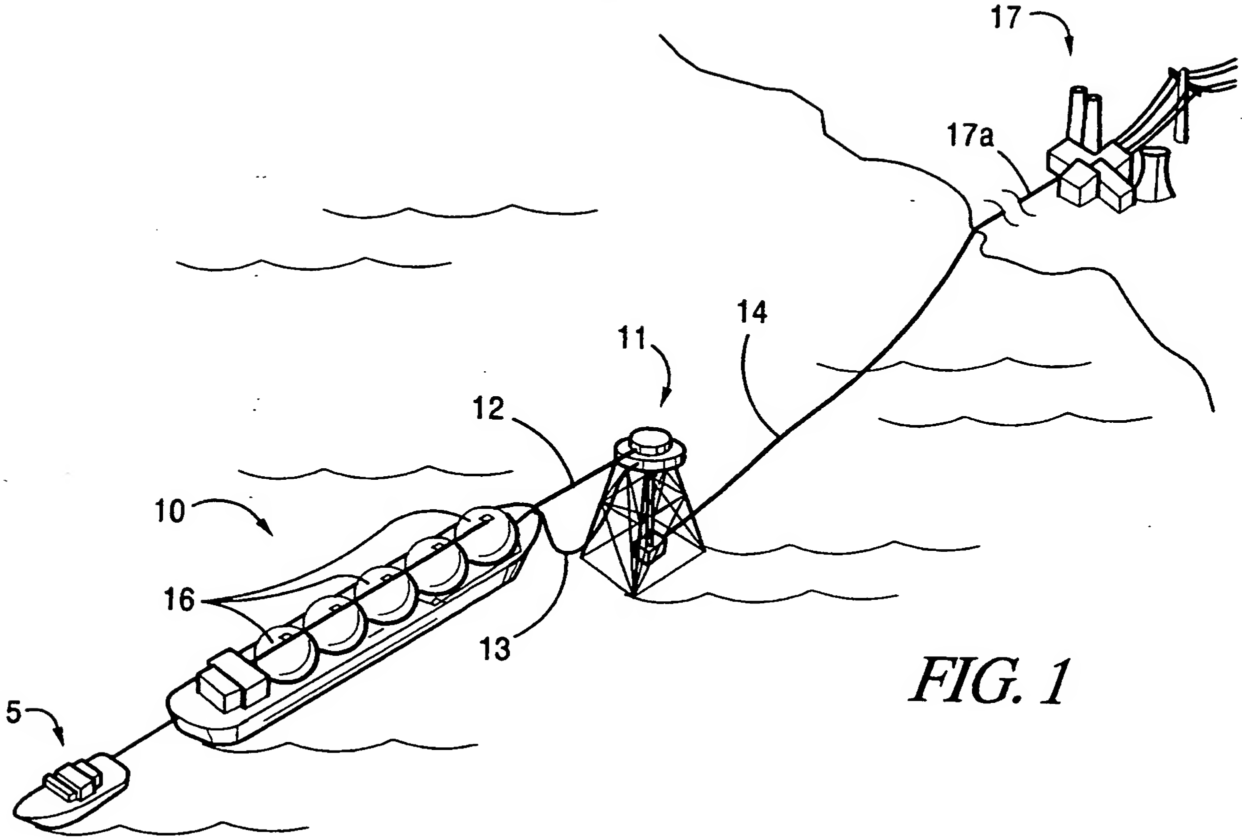

FIG. 1

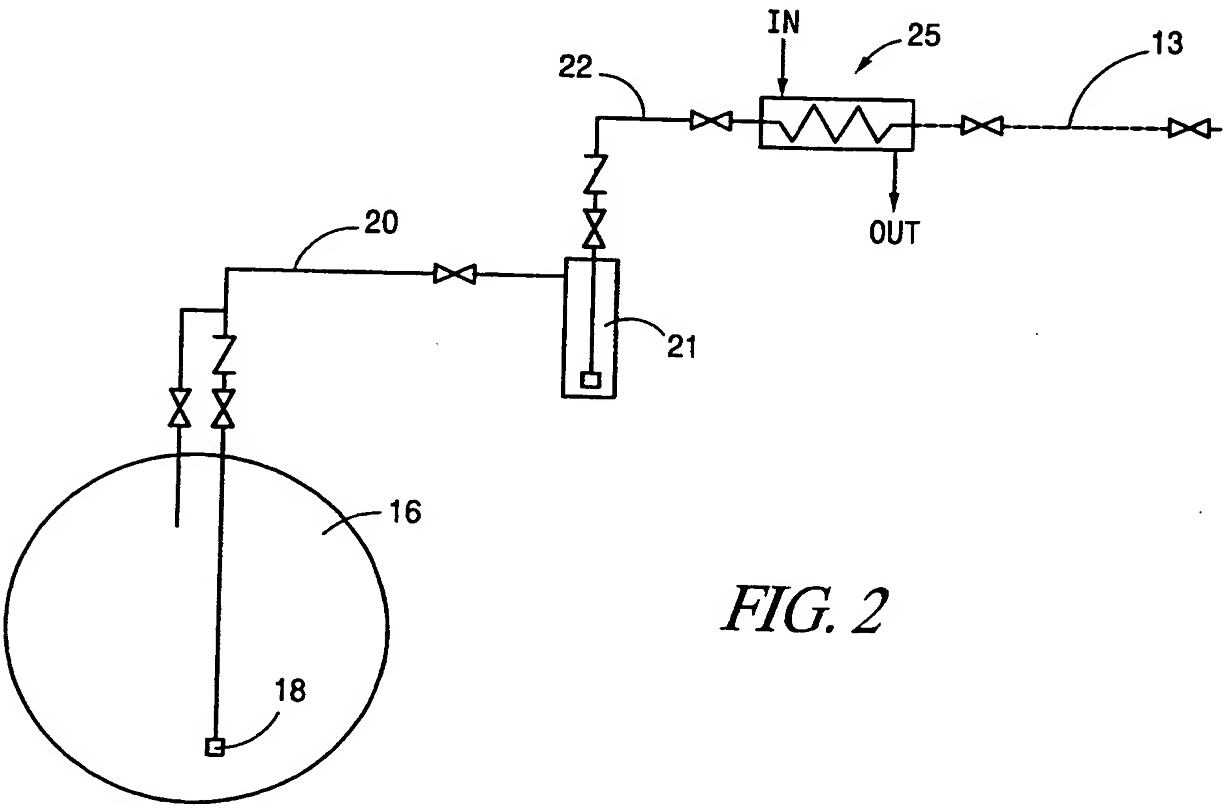

FIG. 2

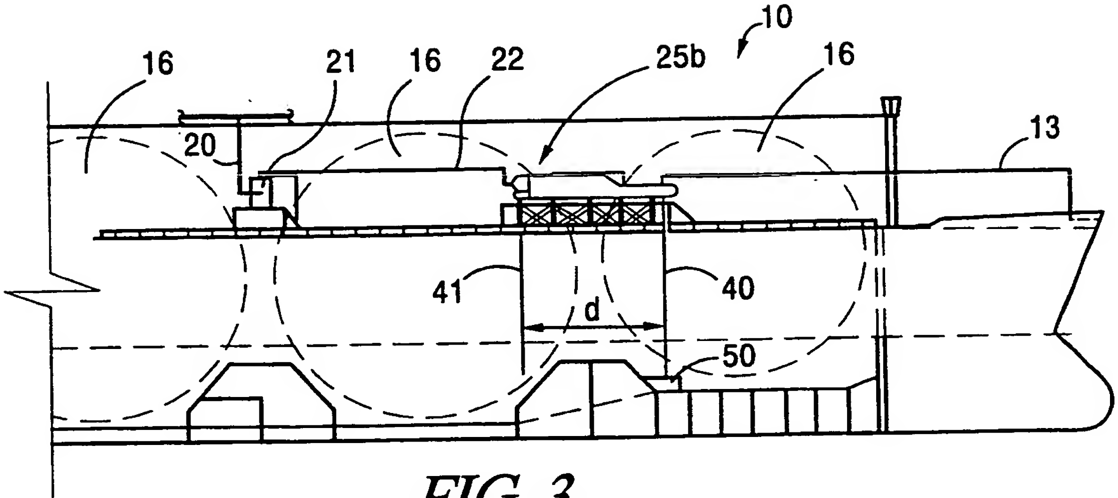

FIG. 3

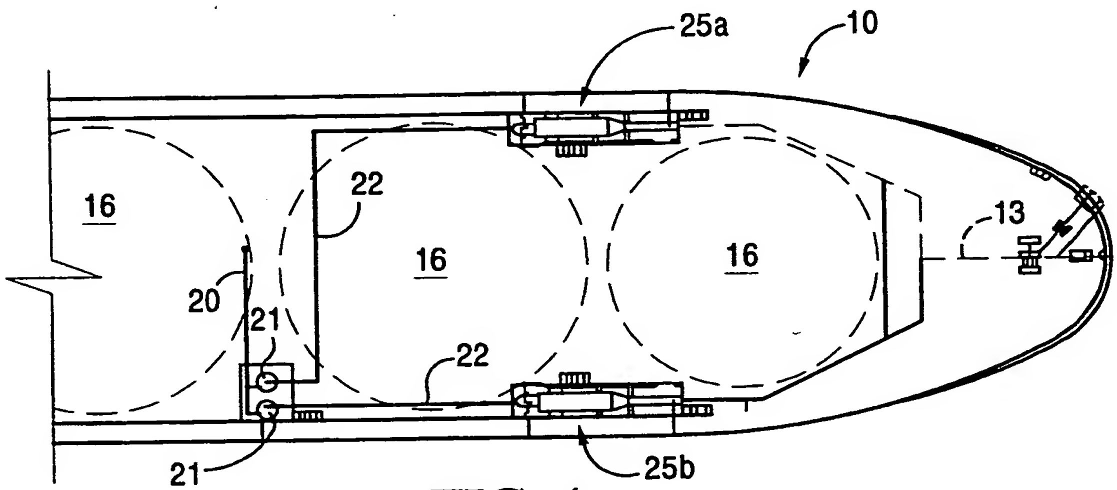

FIG. 4

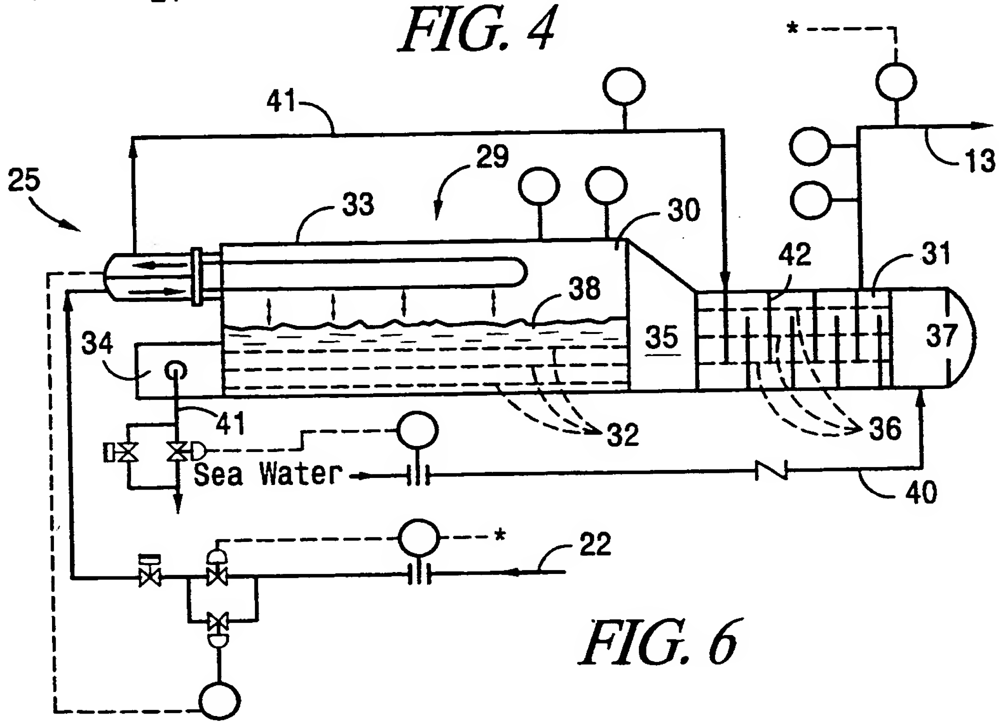

FIG. 6

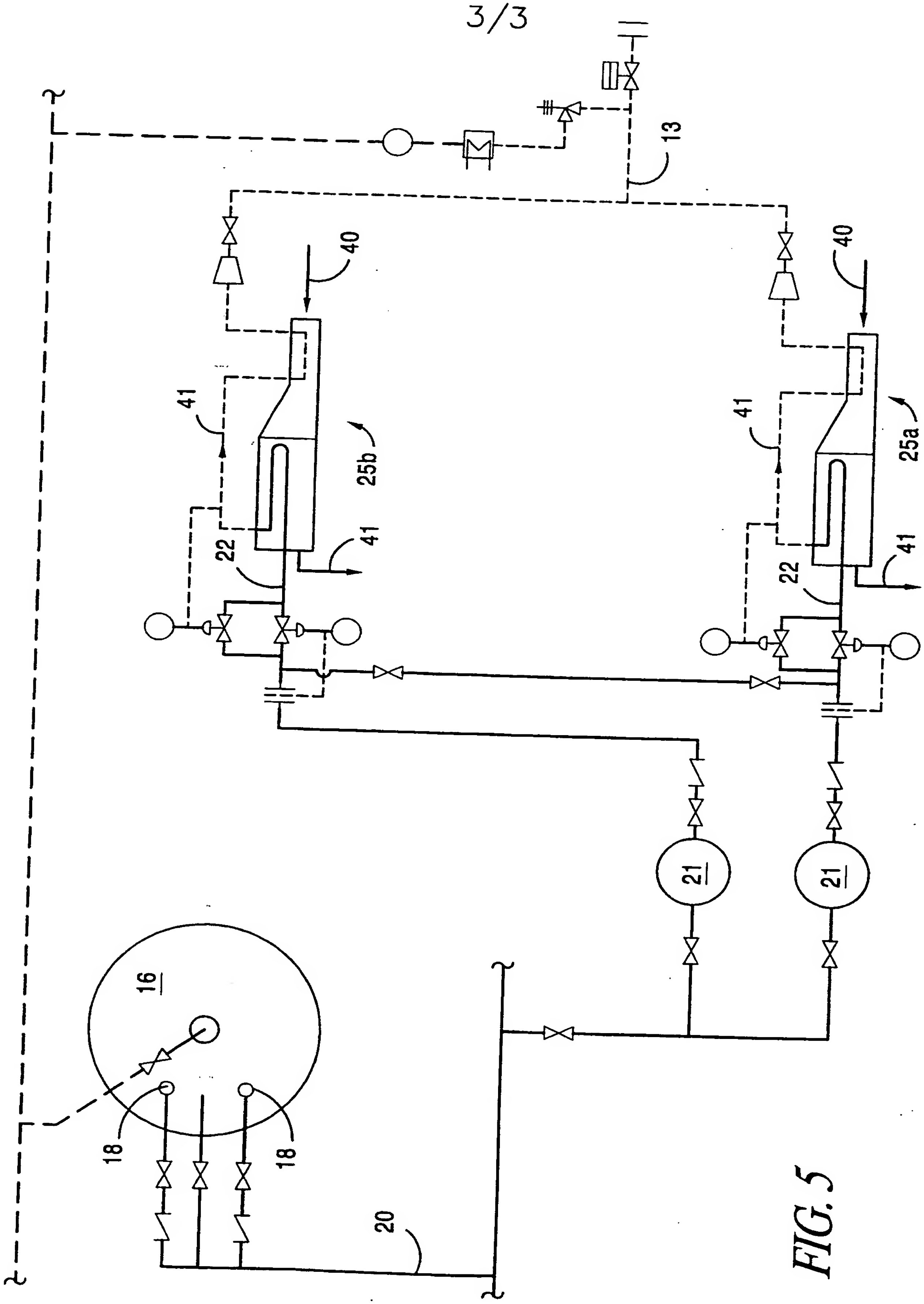

FIG. 5

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INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :F25B 19/00; F17C 9/02; B63B 25/26
US CL :62/7, 50.2, 240
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2,795,937 A (SATTLER ET AL.) 18 JUNE 1957, SEE THE ENTIRE DOCUMENT.	1-7
Y	US 2,940,268 A (MORRISON) 14 JUNE 1960, SEE THE ENTIRE DOCUMENT.	1-7
Y	US 3,535,210 A (LINDE ET AL.) 20 0CTOBER 1976, SEE THE ENTIRE DOCUMENT.	1-7
Y	US 3,986,340 A (BIVINS, JR.) 19 0CTOBER 1976, SEE THE ENTIRE DOCUMENT.	1-7
A	US 4,033,135 A (MANDRIN) 05 JULY 1977, SEE THE ENTIRE DOCUMENT.	1-7

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